INTERNATIONAL JOURNAL OF RESEARCH AND SCIENTIFIC INNOVATION (IJRSI)
ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue X October 2025

Virtual Experiment–Based Kit as an Innovative Approach to Chemistry Education for Secondary School Students

Chua Kok Yong, Syaza Hazwani Binti Zaini, Wong Kung Teck, Lian Tiau Seng

Faculty of Human Development, Universiti Pendidikan Sultan Idris, 35900 Tanjong Malim, Perak, Malaysia.

DOI: https://dx.doi.org/10.51244/IJRSI.2025.1210000178

Received: 20 October 2025; Accepted: 28 October 2025; Published: 14 November 2025

ABSTRACT

The rapid growth of digital technology is reshaping science education, particularly in chemistry where laboratory work is often constrained by cost, safety, and limited resources. These challenges are especially pressing in Malaysian Independent Chinese Secondary Schools (MICSS), where many laboratories lack updated facilities and technical support. This study sets out to design and evaluate a virtual experiment–based kit to supplement chemistry teaching and learning. A quasi-experimental design will be carried out with about 30 Junior 3 students in MICSS. Data will be collected through a Chemistry Knowledge Test, an Experimental Skills Test, and a Student Feedback Questionnaire, analyzed using descriptive and inferential statistics, supported by qualitative insights. Expected outcomes include stronger conceptual understanding, improved laboratory skills, and greater interest in STEM learning. The study also seeks to highlight challenges in teacher readiness and technological infrastructure, offering practical guidance for the effective integration of virtual experiments in MICSS classrooms.

Keywords: Virtual Experiments, Chemistry Education, MICSS, Educational Technology, STEM, Artificial Intelligence, Virtual Reality

INTRODUCTION

The rapid development of information technology has reshaped education in profound ways, introducing new teaching methods and powerful tools for learning. One of the most significant innovations is the use of virtual experiments, particularly in chemistry education. Virtual simulation platforms, such as the Obel Chemical Virtual Simulation Experiment Software, are increasingly recognized as valuable teaching aids, providing safe and cost-effective alternatives to traditional laboratory practices (Mai & Muruges, 2022).

This study not only explores how virtual experiments can be applied in secondary school chemistry but also sets out to design and evaluate a virtual experiment–based kit specifically tailored for Malaysian Independent Chinese Secondary Schools (MICSS). The initiative responds to well-documented challenges in conventional chemistry teaching—shortages of equipment, safety risks, and the high cost of consumables (Md Hassan et al., 2020; Yılmaz, 2023; "The Changes and Challenges of Educational Technology Innovation on the Role of Teachers," 2024).

Chemistry, as an experimental science, depends on students being able to observe and engage with reactions directly. Yet, physical laboratory constraints often restrict such opportunities. Virtual experiments offer a practical solution by creating an interactive and flexible environment where students can safely repeat procedures without the limitations of equipment or materials (Abdullah, 2017). This approach is especially relevant in Malaysia, where teenagers' strong engagement with digital technology creates fertile ground for integrating virtual learning tools into classrooms (Cha & Seo, 2018;Fischer-Grote et al., 2019).

In recent years, Malaysian teenagers have shown significant growth in their use of digital technology. According to the Malaysian Communications and Multimedia Commission (MCMC) and Soh et al. (2012), Internet penetration among Malaysian teenagers has reached more than 90 percent, particularly in urban areas, where about 85 percent of teenagers have access to smartphones and tablets and spend an average of more than four

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue X October 2025

hours a day on the Internet (Cha & Seo, 2018;Fischer-Grote et al., 2019; Haug et al., 2015; *Malaysia: Daily Screen Time Online by Activity 2022 | Statista)*. This shift in technology usage indicates that digital tools, including virtual lab platforms, are well-positioned to resonate with students' learning habits and enhance their engagement with science.

The shift was further accelerated by the COVID-19 pandemic, during which the Ministry of Education promoted digital tools through initiatives such as the "MyDigital Programme" to ensure learning continuity during school closures. Virtual laboratories played a central role, enabling teachers and students to continue conducting experiments in an online setting while minimizing health and safety risks (Positioning Malaysia As A Regional Leader In The Digital Economy: The Economic Opportunities Of Digital Transformation And Google's Contribution, 2021).

Therefore, this study aims

1. To analyze the major challenges and limitations of conventional chemistry laboratory teaching in Malaysian Independent Chinese Secondary Schools (MICSS).
2. To identify the needs and opportunities for integrating virtual experiments as a supplementary approach in MICSS chemistry education.

This study seeks to answer the following research questions:

1. How effective is the virtual experiment–based program in improving chemistry knowledge and laboratory skills among MICSS students?
2. What are the perceptions and learning experiences of students using the virtual experiment–based program compared to conventional laboratory methods?

This research carries particular significance because Malaysian Independent Chinese Secondary Schools (MICSS) face resource limitations that are often more severe than those in public schools. Although many studies have explored the use of virtual experiments in mainstream secondary education, very few have examined their application within the MICSS setting. The novelty of this study lies in its focus on systematically designing and evaluating a virtual experiment–based kit tailored to the realities of MICSS. At the same time, it considers how emerging technologies such as Artificial Intelligence (AI), Virtual Reality (VR), and Augmented Reality (AR) could further enrich chemistry learning experiences.

In essence, the problem addressed in this study is the lack of safe and effective opportunities for laboratory practice in MICSS, largely due to financial and infrastructural constraints. The research gap lies in the absence of empirical studies that demonstrate how virtual experiment kits can be purposefully designed, implemented, and evaluated within this unique context. By filling this gap, the study aims to provide not only a practical solution for MICSS but also a replicable framework for integrating digital innovations into chemistry education more broadly.

Need for this study

Many Malaysian Independent Chinese Secondary Schools (MICSS) continue to struggle with laboratory-based teaching due to financial limitations, outdated facilities, and the shortage of trained laboratory technicians. These challenges not only raise safety concerns but also reduce students' opportunities for meaningful hands-on experience (Dong Zong Blueprint Consultation, 2017; Idris et al., 2023). In addition, the successful adoption of Virtual Learning Environments (VLE) among teachers is strongly influenced by social factors, technological support, and teacher self-efficacy. Adequate infrastructure, reliable internet access, and continuous professional training are therefore essential for integrating digital tools effectively into teaching and learning (Ahmad et al., 2023).

To address these constraints, the Malaysian government has encouraged the use of digital education and virtual experiments. However, despite these efforts, STEM enrollment continues to decline, raising concerns about the country's future talent pipeline (Idris & Bacotang, 2023; *Insufficient Graduates with STEM Skills May Impact Industrial and Economic Growth, Says Mustapha)*. While virtual experiments provide a safe and cost-effective

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue X October 2025

alternative, current research has not sufficiently examined how they can be systematically integrated with traditional experiments to maximize learning outcomes (Nechypurenko et al., 2023). Without such a structured approach, students may still fall short in developing essential laboratory skills, limiting their readiness for higher education and careers in STEM fields.

BACKGROUND

Chemistry learning relies on both virtual and laboratory-based experiments, each offering distinct advantages. Virtual experiments enhance flexibility, safety, and cost-effectiveness (Nechypurenko et al., 2023), hile traditional laboratory experiments provide essential hands-on skills for scientific inquiry (Marinkovic et al., 2022). However, the absence of dedicated laboratory technicians and insufficient safety training among teachers has led many schools to avoid conducting high-risk experiments, such as those involving strong acids, organic solvents, or combustion reactions(Idris et al., 2023).

To overcome these constraints, the Malaysian government has actively promoted digital education and encouraged the adoption of virtual experiments in STEM education (Idris & Bacotang, 2023). Such tools enhance accessibility, particularly in rural areas, and increase student engagement with scientific concepts (Danmali et al., 2024). Nevertheless, despite these initiatives, science enrollment remains low, prompting additional efforts through programs such as MySTEM(Statistik Pendidikan Tinggi 2023 : Kementerian Pendidikan Tinggi).

MICSS face persistent financial and resource limitations, resulting in outdated laboratories and reduced opportunities for hands-on practice (Dong Zong Blueprint Consultation, 2017). The shortage of qualified teachers and inadequate safety measures further constrain experimental learning (Idris et al., 2023). Virtual experiments can help mitigate these challenges by lowering costs (Zhang & Liu, 2023), enhancing safety, enhancing safety (Hamed & Aljanazrah, 2020), and providing opportunities for repeated practice (Shana & Abulibdeh, 2020). However, effective chemistry education requires a structured integration of both approaches. While virtual experiments continue to expand, issues of affordability (Gao & Zhu, 2023) and teacher readiness remain critical (Education Ministry’s RM100,000 Initiative to Integrate STEM Culture in Schools, 2024). Moreover, emerging technologies such as Virtual Reality (VR) and Augmented Reality (AR) hold potential to further strengthen their impact (Al-Ansi et al., 2023).

In summary, optimizing chemistry education in MICSS requires a balanced integration of virtual and laboratory-based experiments. Successful implementation depends on adequate teacher training, pedagogical strategies, and sustainable infrastructure to ensure both approaches complement each other in supporting STEM learning.

Educational technology theories and learning theories supporting virtual experiments

Several educational technology and learning theories provide a strong foundation for the use of virtual experiments. The **SAMR Model** (Romrell et al.) describes technology integration in four progressive stages—substitution, augmentation, modification, and redefinition. Applied to virtual chemistry experiments, this model helps explain how digital tools can go beyond simply replacing traditional labs, enabling richer experiences such as multi-variable testing and real-time simulations (Hamilton et al., 2016).

Mayer’s **Cognitive Theory of Multimedia Learning**(Mayer, 2010) emphasizes the value of combining text, visuals, and interactive elements. Within a virtual lab, this multimodal approach supports deeper understanding of abstract chemical concepts (Chong & Muzhou, 2024). Similarly, **Constructivist Learning Theory** (Prakash Chand, 2023) highlights the importance of active engagement. By allowing students to manipulate variables, test hypotheses, and receive instant feedback, virtual experiments create authentic learning opportunities(van Riesen et al., 2018).

Meanwhile, **Bloom’s Taxonomy** (Anderson and Krathwohl Bloom’s Taxonomy Revised Understanding the New Version of Bloom’s Taxonomy) provides a clear framework for cognitive development, moving from remembering and understanding to higher-order skills such as analyzing, evaluating, and creating. Virtual

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue X October 2025

experiments align well with this progression, as they encourage both conceptual mastery and problem-solving (Abdinejad et al., 2021).

Finally, evidence from blended learning research in Malaysia suggests that integrating social interaction and peer collaboration into digital platforms significantly increases student participation (Hanif et al., 2022). Extending these principles to virtual chemistry experiments could further strengthen engagement and collaborative learning.

Challenges of conventional chemistry experiments

Traditional chemistry experiments face several obstacles that limit their overall effectiveness. Many schools struggle with resource and equipment shortages, making it difficult to maintain fully equipped laboratories and thereby restricting students' opportunities for practical, hands-on experience (Gebremichael Alema et al., 2024). Concerns about safety—particularly when handling hazardous chemicals or carrying out high-risk reactions—also reduce the range of experiments that can be conducted ((Aliyo & Edin, 2023).

Time and space constraints within school schedules further limit students' access to laboratory facilities, leaving them with fewer chances to practice essential experimental skills (Teig et al., 2019). On top of this, a lack of sufficient teacher training means that many educators are not fully equipped to guide students effectively through experimental activities (Keskin Geçer & Zengin, 2015). Together, these barriers highlight the persistent challenges that schools face in providing meaningful laboratory-based learning experiences.

Global adoption and application of virtual experiments

Virtual experiments provide a flexible, safe, and cost-effective alternative to traditional chemistry laboratories, effectively addressing many of the challenges faced by schools. Around the world, several education systems have already begun integrating virtual labs into their teaching practices with promising results.

In China, virtual experiments were officially introduced into the national chemistry curriculum in 2019, leading to significant improvements in experimental learning, particularly in rural schools where resources are limited (Zhang & Liu, 2023). In the United States, platforms such as PhET Interactive Simulations have been widely used to strengthen students' conceptual understanding of molecular interactions and chemical equilibria (Diab et al., 2024). Finland has adopted an innovative approach by combining virtual experiments with gamification and problem-based learning, encouraging higher-order thinking and creativity among students (Kupiainen, 2022). Meanwhile, in Germany, the integration of Virtual Reality (VR) and Augmented Reality (AR) into virtual laboratories has created immersive and interactive experimental experiences, bringing chemistry concepts to life in new and engaging ways (Bullock et al., 2024).

The potential of virtual experiments in micss education reform

The integration of virtual experiments in MICSS is consistent with the goals of the Malaysia Independent Chinese Secondary Schools Education Blueprint, which highlights the importance of technology in improving learning quality. Research shows that technology-driven approaches encourage students to embrace challenges, learn from mistakes, foster cooperative learning, and cultivate both personal responsibility and motivation to succeed (Ghani et al., 2019).

Virtual experiments, in particular, promote self-directed learning by allowing students to explore and repeat experiments at their own pace, strengthening their problem-solving abilities (Flegr et al., 2023). They also stimulate creativity by enabling learners to independently design and manipulate experimental variables, encouraging innovation in the learning process (Chen et al., 2024).

At the same time, virtual platforms create opportunities for collaborative learning. Students can work together in digital environments, engaging in discussions, sharing results, and collectively interpreting findings (Aw et al., 2020). As Termizi Borhan (2013) noted, group activities such as brainstorming, debating, and resource sharing not only help students exchange ideas but also validate arguments and reach better solutions. These examples illustrate how educational innovations like virtual experiments can meaningfully enhance teamwork and improve learning outcomes.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue X October 2025

Challenges in implementing virtual experiments in micss

Despite their many benefits, several challenges continue to limit the full implementation of virtual experiments in MICSS. One major barrier is technological infrastructure. Some schools, particularly those in rural areas, lack the necessary hardware and stable internet connectivity to effectively support virtual laboratories (Dong Zong Blueprint Consultation, 2017).

Another key issue is the lack of teacher training and digital literacy. Many educators are still unfamiliar with integrating virtual experiments into their teaching practice, which reduces the likelihood of successful adoption (Wohlfart et al., 2023). In addition, striking the right balance between virtual and physical laboratory work remains a concern. While virtual experiments can replicate chemical processes and reactions, they cannot fully substitute the practical skills gained from handling real equipment and materials, such as preparing reagents or managing lab safety procedures (Chan et al., 2021).

Future directions and prospects for virtual experiments

The future of virtual experiments is expected to be shaped by rapid advancements in artificial intelligence (AI), virtual reality (VR), and augmented reality (AR). AI-powered virtual laboratories can offer personalized learning pathways and provide real-time corrective feedback, helping students stay engaged and improving their overall learning outcomes (Amirbekova et al., 2023).

At the same time, VR and AR technologies add a new dimension of immersion, allowing students to observe and interact with chemical reactions in three-dimensional simulations. This makes abstract concepts more concrete and easier to grasp (Jagodziński & Wolski, 2015).

Beyond chemistry, interdisciplinary applications will further expand the potential of virtual experiments by integrating concepts from physics, biology, and environmental science. Such cross-disciplinary approaches can cultivate a broader and more connected understanding of science as a whole (Chansa Chanda et al., 2024).

Research Timeline

The project is expected to be completed within 20 weeks. The timeline is carefully designed to move step by step from identifying the challenges of conventional chemistry laboratory teaching in Malaysian Independent Chinese Secondary Schools (MICSS) toward the design and proposal of a virtual experiment–based kit.

The first phase (Weeks 1–7) centers on analyzing the challenges and mapping the specific needs of MICSS, which form the foundation and justification for virtual experiments. The second phase (Weeks 8–13) builds the theoretical framework, refines the research objectives and questions, and ensures that the study remains aligned with the identified challenges. The third phase (Weeks 14–17) focuses on the design and development of the virtual experiment kit, serving as a direct response to the earlier findings. Finally, the last phase (Weeks 18–20) details the research methodology, outlines the expected outcomes, and presents the conclusion together with future directions.

This structure ensures that every stage of the study is logically connected, forming a coherent chain of Challenges → Need → Design & Development → Evaluation. Most importantly, it highlights that the design and development of the virtual experiment kit are not abstract tasks, but a direct response to the real challenges and needs faced by MICSS.

Week	Activity	Purpose / Link to Research Logic
1	Title Refinement	Define research focus based on challenges in MICSS.
2–3	Introduction Drafting	Establish background and highlight cabaran (limitations of laboratories, safety issues, high costs).

4–5	Identifying Challenges	Review literature and consult relevant documents to analyze limitations of conventional chemistry lab teaching.
6–7	Mapping Research Needs	Translate identified challenges into clear needs and opportunities for integrating virtual experiments in MICSS.
8–11	Background & Literature Review	Consolidate theoretical foundation (SAMR, CTML, Constructivism, Bloom's Taxonomy) to justify the need for a virtual experiment kit.
12	Defining Research Objectives & Questions	Ensure objectives directly address challenges and identified needs.
13	Theoretical Framework Construction	Connect challenges with the framework guiding the design of the virtual experiment kit.
14–16	Designing the Virtual Experiment Kit	Based on identified needs, propose features and structure of the kit.
17	Instrument Development	Prepare Chemistry Knowledge Test, Experimental Skills Test, and Student Feedback Questionnaire to support the evaluation of the designed kit.
18	Methodology Drafting	Detail quasi-experimental design with Junior 3 MICSS students (n≈30).
19	Expected Outcomes & Discussion Draft	Frame outcomes as solutions to cabaran: improved knowledge, laboratory skills, and STEM interest.
20	Conclusion & Future Work	Summarize contributions and outline future directions, emphasizing how challenges necessitated the design of the kit.

REFERENCES

1. Abdinejad, M., Ferrag, C., Qorbani, H. S., & Dalili, S. (2021). Developing a Simple and Cost-Effective Markerless Augmented Reality Tool for Chemistry Education. Journal of Chemical Education, 98(5), 1783–1788. https://doi.org/10.1021/acs.jchemed.1c00173
2. Abdullah, N. (2017). Development of Interactive Software for Implementing the Science Process Skills in Science Primary School. International Journal of Academic Research in Business and Social Sciences, 7(6). https://doi.org/10.6007/ijarbss/v7-i6/3033
3. Ahmad, N. L., Yahaya, R., Wahid, H. A., & Fazil, N. S. M. (2023). Role of social factors, self-efficacy and technological support on the use of virtual learning environment among teachers. International Journal of Evaluation and Research in Education, 12(1), 369–376. https://doi.org/10.11591/ijere.v12i1.22628
4. Al-Ansi, A. M., Jaboob, M., Garad, A., & Al-Ansi, A. (2023). Analyzing augmented reality (AR) and virtual reality (VR) recent development in education. Social Sciences and Humanities Open, 8(1). https://doi.org/10.1016/J.SSAHO.2023.100532
5. Aliyo, A., & Edin, A. (2023). Assessment of Safety Requirements and Their Practices Among Teaching Laboratories of Health Institutes. Microbiology Insights, 16, 117863612311744. https://doi.org/10.1177/11786361231174414
6. Amirbekova, E., Shertayeva, N., & Mironova, E. (2023). Teaching chemistry in the metaverse: the effectiveness of using virtual and augmented reality for visualization. Frontiers in Education, 8. https://doi.org/10.3389/feduc.2023.1184768
7. Anderson and Krathwohl Bloom's Taxonomy Revised Understanding the New Version of Bloom's Taxonomy. (n.d.).

8. Aw, J. K., Boellaard, K. C., Tan, T. K., Yap, J., Loh, Y. P., Colasson, B., Blanc, étienne, Lam, Y., & Fung, F. M. (2020). Interacting with Three-Dimensional Molecular Structures Using an Augmented Reality Mobile App. Journal of Chemical Education, 97(10), 3877–3881. https://doi.org/10.1021/acs.jchemed.0c00387
9. Bullock, M., Graulich, N., & Huwer, J. (2024). Using an Augmented Reality Learning Environment to Teach the Mechanism of an Electrophilic Aromatic Substitution. Journal of Chemical Education, 101(4), 1534–1543. https://doi.org/10.1021/acs.jchemed.3c00903
10. Cha, S. S., & Seo, B. K. (2018). Smartphone use and smartphone addiction in middle school students in Korea: Prevalence, social networking service, and game use. Health Psychology Open, 5(1). https://doi.org/10.1177/2055102918755046
11. Chan, P., Van Gerven, T., Dubois, J.-L., & Bernaerts, K. (2021). Virtual chemical laboratories: A systematic literature review of research, technologies and instructional design. Computers and Education Open, 2, 100053. https://doi.org/10.1016/J.CAEO.2021.100053
12. Chansa Chanda, T., Hassan Sain, Z., Shogbesan, Y., Matthew Akpan, W., Chansa Thelma, C., Olayinka Shogbesan, Y., & Vinandi Phiri, E. (2024). Digital Literacy in Education: Preparing Students for the Future Workforce Article in. International Journal of Research (IJR) International Journal of Research. https://doi.org/10.5281/ZENODO.13347718
13. Chen, C. M., Li, M. C., & Tu, C. C. (2024). A Mixed Reality-Based Chemistry Experiment Learning System to Facilitate Chemical Laboratory Safety Education. Journal of Science Education and Technology. https://doi.org/10.1007/S10956-024-10101-3
14. Chong, W., & Muzhou, T. (2024). Teaching Design of High School Chemistry Virtual Experiment in Blended Learning Environment. Advances in Educational Technology and Psychology, 8(4), 39–44. https://doi.org/10.23977/AETP.2024.080406
15. Danmali, S. S., Onansanya, S. A., Atanda, F. A., & Abdullahi, A. (2024). Application of Virtual Reality in STEM Education for Enhancing Immersive Learning and Performance of At-Risk Secondary School Students. International Journal of Research and Innovation in Social Science, VIII(IIIS), 3971–3984. https://doi.org/10.47772/IJRISS.2024.803288S
16. Diab, H., Daher, W., Rayan, B., Issa, N., & Rayan, A. (2024). Transforming Science Education in Elementary Schools: The Power of PhET Simulations in Enhancing Student Learning. Multimodal Technologies and Interaction 2024, Vol. 8, Page 105, 8(11), 105. https://doi.org/10.3390/MTI8110105
17. Dong Zong BluePrint Consultation. (2017).
18. Education Ministry's RM100,000 initiative to integrate STEM culture in schools. (n.d.). Retrieved August 17, 2024, from https://www.nst.com.my/news/nation/2024/01/1003191/education-ministrys-rm100000-initiative-integrate-stem-culture-schools
19. Fischer-Grote, L., Kothgassner, O. D., & Felnhofer, A. (2019). Risk factors for problematic smartphone use in children and adolescents: a review of existing literature. Neuropsychiatrie : Klinik, Diagnostik, Therapie Und Rehabilitation : Organ Der Gesellschaft Osterreichischer Nervenarzte Und Psychiater, 33(4), 179–190. https://doi.org/10.1007/S40211-019-00319-8
20. Flegr, S., Kuhn, J., & Scheiter, K. (2023). When the whole is greater than the sum of its parts: Combining real and virtual experiments in science education. Computers & Education, 197, 104745. https://doi.org/10.1016/J.COMPEDU.2023.104745
21. Gao, Y., & Zhu, X. (2023). Research on the learning experience of virtual simulation class experimental teaching and learning based on the perspective of nursing students. BMC Nursing, 22(1). https://doi.org/10.1186/s12912-023-01534-z
22. Gebremichael Alema, B., Mebrahtu Tesfamariam, G., Gebreyohannes Berhe, G., & Teklu Gebretsadik, T. (2024). Practices and challenges in implementing chemistry laboratory work in secondary schools: a review. African Journal of Chemical Education-AJCE, 14(2), 14.
23. Ghani, M. T. A., Hamzah, M., Daud, W. A. A. W., & Ramli, S. (2019). The Conceptual Framework for Learning Arabic Vocabulary through Educational Digital Game. In International Journal of Education (Vol. 4, Issue 25). www.ijepc.com
24. Hamed, G., & Aljanazrah, A. (2020). The effectiveness of using virtual experiments on students' learning in the general physics LAB. Journal of Information Technology Education: Research, 19, 977–996. https://doi.org/10.28945/4668

25. Hamilton, E. R., Rosenberg, J. M., & Akcaoglu, M. (2016). The Substitution Augmentation Modification Redefinition (SAMR) Model: a Critical Review and Suggestions for its Use. TechTrends, 60(5), 433–441. https://doi.org/10.1007/s11528-016-0091-y
26. Hanif, H., Hamzah, M., & Harun, R. N. S. R. (2022). Optimizing Participation with Helpers to Enhance Interaction in a Blended Learning Environment. International Journal of Emerging Technologies in Learning, 17(17), 155–170. https://doi.org/10.3991/ijet.v17i17.26415
27. Haug, S., Paz Castro, R., Kwon, M., Filler, A., Kowatsch, T., & Schaub, M. P. (2015). Smartphone use and smartphone addiction among young people in Switzerland. Journal of Behavioral Addictions, 4(4), 299–307. https://doi.org/10.1556/2006.4.2015.037
28. Idris, R., & Bacotang, J. (2023). Exploring STEM Education Trends in Malaysia: Building a Talent Pool for Industrial Revolution 4.0 and Society 5.0. International Journal of Academic Research in Progressive Education and Development, 12(2). https://doi.org/10.6007/ijarped/v12-i2/16825
29. Idris, R., Govindasamy, P., & Nachiappan, S. (2023). Challenge and Obstacles of STEM Education in Malaysia. International Journal of Academic Research in Business and Social Sciences, 13(4). https://doi.org/10.6007/ijarbss/v13-i4/16676
30. Insufficient graduates with STEM skills may impact industrial and economic growth, says Mustapha. (n.d.). Retrieved August 17, 2024, from https://www.nst.com.my/news/nation/2024/05/1046120/insufficient-graduates-stem-skills-may-impact-industrial-and-economic
31. Jagodziński, P., & Wolski, R. (2015). Assessment of Application Technology of Natural User Interfaces in the Creation of a Virtual Chemical Laboratory. Journal of Science Education and Technology, 24(1), 16–28. https://doi.org/10.1007/s10956-014-9517-5
32. Keskin Geçer, A., & Zengin, R. (2015). Science Teachers' Attitudes Towards Laboratory Practises and Problems Encountered. In International Journal of Education and Research (Vol. 3, Issue 11). www.ijern.com
33. Kupiainen, R. (2022). Making the "digital leap" in Finnish schools. Nordisk Tidsskrift for Pedagogikk Og Kritikk, 8(2022), 287. https://doi.org/10.23865/NTPK.V8.4068
34. Mai, M. Y., & Muruges, G. R. (2022). Primary School Science Teachers' Attitude towards Using Virtual Learning Environment (VLE) In Teaching Science. European Journal of Education, 5(1), 129–140. https://doi.org/10.26417/ejed.v1i3.p155-162
35. Malaysia: daily screen time online by activity 2022 | Statista. (n.d.). Retrieved August 17, 2024, from https://www.statista.com/statistics/803614/daily-time-spent-using-online-media-by-activity-malaysia/
36. Marinkovic, N., Sasaki, K., Adzic, R. R., Rodrigues, M., & Carvalho, S. (2022). Physics Education Virtual experimental activities: a new approach You may also like (Invite) Insights in Measuring Particle Size of Multiatomic Nanoparticles By XAS Virtual experimental activities: a new approach.
37. Mayer, R. E. . (2010). Multimedia learning. Cambridge University Press.
38. Md Hassan, N., Majid, N. A., & Hassan, N. K. A. (2020). Validation of learning environment inventory for secondary school contexts. International Journal of Evaluation and Research in Education, 9(2), 379–384. https://doi.org/10.11591/ijere.v9i2.20444
39. Nechypurenko, P. P., Chernova, M. P., Evangelist, O. O., & Selivanova, T. V. (2023). Enhancing student research activities through virtual chemical laboratories: a case study on the topic of Solutions. Educational Technology Quarterly, 2023(2), 188–209. https://doi.org/10.55056/ETQ.603
40. Positioning malaysia as a regional leader in the digital economy: the economic opportunities of digital transformation and google's contribution. (2021).
41. Prakash Chand, S. (2023). Constructivism in Education: Exploring the Contributions of Piaget, Vygotsky, and Bruner. International Journal of Science and Research (IJSR), 12(7), 274–278. https://doi.org/10.21275/sr23630021800
42. Romrell, D., Kidder, L. C., & Wood, E. (n.d.). The SAMR Model as a Framework for Evaluating mLearning.
43. Shana, Z., & Abulibdeh, E. S. (2020). Science practical work and its impact on students' science achievement. Journal of Technology and Science Education, 10(2), 199–215. https://doi.org/10.3926/JOTSE.888
44. Soh, P. C. H., Yan, Y. L., Ong, T. S., & Teh, B. H. (2012). Digital divide amongst urban youths in Malaysia - Myth or reality? Asian Social Science, 8(15), 75–85. https://doi.org/10.5539/ass.v8n15p75

45. Statistik Pendidikan Tinggi 2023 : Kementerian Pendidikan Tinggi. (n.d.).
46. Teig, N., Scherer, R., & Nilsen, T. (2019). I know i can, but do i have the time? The role of teachers' self-efficacy and perceived time constraints in implementing cognitive-activation strategies in science. Frontiers in Psychology, 10(JULY). https://doi.org/10.3389/fpsyg.2019.01697
47. Termizi Borhan, M., & Md Yassin, S. (n.d.). The 4 th International Research Symposium on Problem-Based Learning (IRSPBL) 2013 Implementation of Problem Based Learning (PBL)-in a Malaysian Teacher Education Course: Issues and Benefits From Students Perspective.
48. The Changes and Challenges of Educational Technology Innovation on the Role of Teachers. (2024). Advances in Educational Technology and Psychology, 8(5). https://doi.org/10.23977/aetp.2024.080526
49. van Riesen, S., Gijlers, H., Anjewierden, A., & de Jong, T. (2018). Supporting learners' experiment design. Educational Technology Research and Development, 66(2), 475–491. https://doi.org/10.1007/S11423-017-9568-4/TABLES/2
50. Wohlfart, O., Wagner, A. L., & Wagner, I. (2023). Digital tools in secondary chemistry education – added value or modern gimmicks? Frontiers in Education, 8. https://doi.org/10.3389/FEDUC.2023.1197296/
51. Yılmaz, Ö. (2023). The Role of Technology in Modern Science Education. Eğitimde Güncel Araştırmalar - VI. https://doi.org/10.58830/OZGUR.PUB383.C1704
52. Zhang, N., & Liu, Y. (2023). Design and implementation of virtual laboratories for higher education sustainability: a case study of Nankai University. Frontiers in Education, 8. https://doi.org/10.3389/feduc.2023.1322263